CLAIMS

What is claimed is:

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1. A data communications system, comprising:

a plurality of individually modulated transmission carriers;

one or more receivers, where each receiver has advance knowledge of relationships between phases of a transmitter's unmodulated carriers; and

a means to synchronize signals between the transmitter and receivers, based on an inherent structure in the frequency domain representation of the received waveform, without additional 'pilot' signals, synchronization patterns, or other special synchronization signals or waveforms.

2. The system of claim 1, where the transmitter's and receivers' signals' sample timing is being synchronized.

3. The system of claim 2, where the individually modulated transmission carriers are Orthogonal Frequency Division Multiplexed carriers.

4. The system of claim 2, where the frequency domain representation of the received signal is a form of the Fourier Transform.

5. The system of claim 4, where the form of the Fourier Transform is the Fast Fourier Transform.

6. The system of claim 2, where the structure of the frequency domain representation is the collective phase relationships between a plurality of individual carriers.

7. The system of claim 6 where the means to synchronize the timing of signals is based on computing the differences in phase between a plurality of individual carriers.

8. The system of claim 7, where the means to compute the differences in phase between individual carriers is by using a differential-in-frequency detection scheme.

9. The system of claim 8 where the differential-in-frequency detection scheme is to multiply a first carrier's complex representation by the complex conjugate of a second carrier's complex representation.

10. The system of claim 7 where the plurality of carriers used are adjacent in frequency.

11. The system of claim 7 where the plurality of carriers used is equally spaced but not adjacent.

12. The system of claim 7 where the plurality of carriers used may not be equally spaced but may be arbitrarily selected by the receivers.

13. The system of claim 6, where the plurality of carriers are used in combination to determine the synchronization, with the contribution of each phase estimate derived from the differential phase of each pair of carriers weighted according to the phase estimate's accuracy.

14. The system of claim 13 where the accuracy of each phase estimate is based on the amplitudes of the carriers used.

15. The system of claim 9 where, for each carrier pair, a first carrier's amplitude and phase, represented as a complex number in a Cartesian coordinate system, is multiplied by a second carrier's amplitude and phase, similarly represented, yielding a complex number representing the combined amplitude as well as the phase difference of the carrier pair; then calculating the vector sum of the plurality of the carrier pairs' combined amplitudes and phase differences; and finally using this vector sum to arrive at a timing synchronization signal.

16. The system of claim 15 where the carriers' modulating data signals are known by the receivers and can be used to determine the precise transmit carriers' phases.

17. The system of claim 15 where the carriers' modulating data signals are not known by the receivers, but can be estimated by attempting to demodulate the carriers and then using the derived modulating data to estimate the transmit carriers' phases.

18. The system of claim 15 where the carriers' modulating data signals are not known by the receivers, but where the effect of the modulation can be removed from the carriers without demodulating the carriers.

19. The system of claim 18 where the means to remove the carriers' data modulation is by raising the complex representation of the carrier amplitude and phase to an integer power.

20. The system of claim 19 where the modulation of the carriers is by N level phase modulation and the data modulation is removed by raising the complex representation of the carrier amplitude and phase to the N^{th} power.

21. The system of claim 20 where the modulation is Quadrature Phase Shift Keying and the data modulation is removed by raising the complex representation of the carrier amplitude and phase to the fourth power.

22. The system of claim 1, where the transmitter's and receivers' operating frequencies are being synchronized.

23. The system of claim 22, where the plurality of transmission carriers are Orthogonal Frequency Division Multiplexed carriers.

24. The system of claim 22, where the frequency domain representation of the received signal is a form of the Fourier Transform.

25. The system of claim 24, where the form of the Fourier Transform is the Fast Fourier Transform.

26. The system of claim 22 where the means to synchronize the operating frequency is based on computing the phases of a plurality of individual carriers.

27. The system of claim 26 where the plurality of carriers are used in combination to determine the synchronization with the contribution of each carrier weighted according to its accuracy.

28. The system of claim 27 where the accuracy of each carrier's contribution is determined based on the carrier's amplitude.

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29. The system of claim 28 where, for each carrier, the carrier's amplitude and phase, represented by a complex number in a Cartesian coordinate system, is summed with the other carriers' complex representation to yield a vector sum, representing the composite amplitude and phase; and a means to use the phase of this composite vector to create a frequency synchronization signal.

30. The system of claim 29 where the carriers' modulating data signals are known by the receivers and can be used to determine the precise transmitter carriers' phases.

31. The system of claim 29 where the carriers' modulating data signals are not known by the receivers but can be estimated by attempting to demodulate the carriers and then used to estimate the transmit carriers' phases.

32. The system of claim 29 where the carriers' modulating data signals are not known by the receivers but where the effect of the modulation can be removed from the carriers without demodulating the carriers.

33. The system of claim 32 where the means to remove the carriers' data modulation is by raising the complex representation of the carrier amplitude and phase to an integer power.

34. The system of claim 33 where the modulation of the carriers is by N level phase modulation and the data modulation is removed by raising the complex representation of the carrier amplitude and phase to the N^{th} power.

35. The system of claim 34 where the modulation is Quadrature Phase Shift Keying and the data modulation is removed by raising the complex representation of the carrier amplitude and phase to the fourth power.

36. The system of claim 1 where the data communications system is a wireless data communications system.

37. The system of claim 36 where the system is subject to a variety of transmission channel impairments.

38. The system of claim 37, where the transmission channel impairments may include noise, interference, time sample misalignment, carrier frequency offset, or delay spread/frequency selective fading, singly or in combination.

39. The system described in claim 14 where, for each carrier pair, a first carrier's amplitude and phase, represented as a complex number in a Cartesian coordinate system, is multiplied by a second carrier's amplitude and phase, similarly represented, yielding a complex number representing the combined amplitude as well as the phase difference of the carrier pair; then calculating the vector sum of the plurality of the carrier pairs' combined amplitudes and phase differences; and finally using this vector sum to arrive at a timing synchronization signal.

40. A method for estimating time and frequency offset in an orthogonal frequency division multiplex system, comprising the steps of:

for any adjacent pair of tones R_i and R_{i+1}, measuring the differential phase from one tone to the next;

adjusting the sampling point to compensate so that the timing offset has the same phase difference between every pair of tones R_i and R_{i+1};

estimating the timing offset across all adjacent tone pairs in a burst; and

estimating the timing offset in the presence of signal impairments;

whereby the noise effects are mitigated by the tone-to-tone differential measurements, thereby creating a weighting of timing estimates based on the likely validity of each estimate.

41. The method of claim 40 wherein said impairments include frequency offset, noise, fading, delay spread/frequency selective fading.

42. A system for estimating time and frequency offset in an orthogonal frequency division multiplex system, comprising:

for any adjacent pair of tones R_i and R_{i+1};

means for measuring the differential phase;

means for adjusting the sampling point to compensate so that the timing offset has the same phase difference between every pair of tones R_i and R_{i+1};

means for estimating the timing offset across all adjacent tone pairs in a burst; and

means for estimating the timing offset in the presence of signal impairments;

whereby the noise effects are mitigated by the tone-to-tone differential measurements, thereby creating a weighting of timing estimates based on the likely validity of each estimate.

43. The system of claim 42 which further comprises said impairments including frequency offset, noise, fading delay spread/frequency selective fading.

44. In a data communications system, including a plurality of individually modulated transmission carriers, the method comprising:

storing information about relationships between a plurality of transmission carrier phases in their unmodulated states at one or more receivers; and

synchronizing signals between the transmitter and receivers, based on an inherent structure in the frequency domain representation of the received waveform, without additional 'pilot' signals, synchronization patterns, or other special synchronization signals or waveforms.

45. The method of claim 44, where the transmitter's and receivers' signals' sample timing is being synchronized.

46. The method of claim 45, where the individually modulated transmission carriers are Orthogonal Frequency Division Multiplexed carriers.

47. The method of claim 45, where the frequency domain representation of the received signal is a form of the Fourier Transform.

48. The method of claim 47, where the form of the Fourier Transform is the Fast Fourier Transform.

49. The method of claim 45, where the structure of the frequency domain representation is the collective phase relationships between a plurality of individual carriers.

50. The method of claim 49, where the synchronizing of the timing of signals is based on computing the differences in phase between a plurality of individual carriers.

51. The method of claim 50, where computing of the differences in phase between individual carriers is by using a differential-in-frequency detection scheme.

52. The method of claim 51 where the differential-in-frequency detection scheme is to multiply a first carrier's complex representation by the complex conjugate of a second carrier's complex representation.

53. The method of claim 50 where the plurality of carriers used are adjacent in frequency.

54. The method of claim 50 where the plurality of carriers used is equally spaced but not adjacent.

55. The method of claim 50 where the plurality of carriers used may not be equally spaced but may be arbitrarily selected by the receivers.

56. The method of claim 49, where the plurality of carriers are used in combination to determine the synchronization, with the contribution of each phase estimate derived from the differential phase of each pair of carriers weighted according to the phase estimate's accuracy.

57. The method of claim 56 where the accuracy of each phase estimate is based on the amplitudes of the carriers used.

58. The method of claim 52 where, for each carrier pair, a first carrier's amplitude and phase, represented as a complex number in a Cartesian coordinate system, is multiplied by a second carrier's amplitude and phase, similarly represented, yielding a complex number representing the combined amplitude as well as the phase difference of the carrier pair; then calculating the vector sum of the plurality of the carrier pairs' combined amplitudes and phase differences; and finally using this vector sum to arrive at a timing synchronization signal.

59. The method of claim 58 where the carriers' modulating data signals are known by the receivers and can be used to determine the precise transmit carriers' phases.

60. The method of claim 58 where the carriers' modulating data signals are not known by the receivers, but can be estimated by attempting to demodulate the carriers and then using the derived modulating data to estimate the transmit carriers' phases.

61. The method of claim 58 where the carriers' modulating data signals are not known by the receivers, but where the effect of the modulation can be removed from the carriers without demodulating the carriers.

62. The method of claim 61 where the means to remove the carriers' data modulation is by raising the complex representation of the carrier amplitude and phase to an integer power.

63. The method of claim 62 where the modulation of the carriers is by N level phase modulation and the data modulation is removed by raising the complex representation of the carrier amplitude and phase to the N^{th} power.

64. The method of claim 63 where the modulation is Quadrature Phase Shift Keying and the data modulation is removed by raising the complex representation of the carrier amplitude and phase to the fourth power.

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65. The method of claim 44, where the transmitter's and receivers' operating frequencies are being synchronized.

66. The method of claim 65, where the plurality of transmission carriers are Orthogonal Frequency Division Multiplexed carriers.

67. The method of claim 65, where the frequency domain representation of the received signal is a form of the Fourier Transform.

68. The method of claim 67, where the form of the Fourier Transform is the Fast Fourier Transform.

69. The method of claim 65 where the means to synchronize the operating frequency is based on computing the phases of a plurality of individual carriers.

70. The method of claim 69 where the plurality of carriers are used in combination to determine the synchronization with the contribution of each carrier weighted according to its accuracy.

71. The method of claim 70 where the accuracy of each carrier's contribution is determined based on the carrier's amplitude.

72. The method of claim 71 where, for each carrier, the carrier's amplitude and phase, represented by a complex number in a Cartesian coordinate system, is summed with the other carriers' complex representation to yield a vector sum, representing the composite amplitude and phase; and a means to use the phase of this composite vector to create a frequency synchronization signal.

73. The method of claim 72 where the carriers' modulating data signals are known by the receivers and can be used to determine the precise transmitter carriers' phases.

74. The method of claim 72 where the carriers' modulating data signals are not known by the receivers but can be estimated by attempting to demodulate the carriers and then used to estimate the transmit carriers' phases.

75. The method of claim 72 where the carriers' modulating data signals are not known by the receivers but where the effect of the modulation can be removed from the carriers without demodulating the carriers.

76. The method of claim 75 where the means to remove the carriers' data modulation is by raising the complex representation of the carrier amplitude and phase to an integer power.

77. The method of claim 76 where the modulation of the carriers is by N level phase modulation and the data modulation is removed by raising the complex representation of the carrier amplitude and phase to the N^{th} power.

78. The method of claim 77 where the modulation is Quadrature Phase Shift Keying and the data modulation is removed by raising the complex representation of the carrier amplitude and phase to the fourth power.

79. The method of claim 44 where the data communications system is a wireless data communications system.

80. The method of claim 79 where the system is subject to a variety of transmission channel impairments.

81. The method of claim 80, where the transmission channel impairments may include noise, interference, time sample misalignment, carrier frequency offset, or delay spread/frequency selective fading, singly or in combination.

82. The method of claim 57 where, for each carrier pair, a first carrier's amplitude and phase, represented as a complex number in a Cartesian coordinate system, is multiplied by a second carrier's amplitude and phase, similarly represented, yielding a complex number representing the combined amplitude as well as the phase difference of the carrier pair; then calculating the vector sum of the plurality of the carrier pairs' combined amplitudes and phase differences; and finally using this vector sum to arrive at a timing synchronization signal.